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SCIENCE

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THE VOLCANIC HISTORY OF LASSEN PEAK¹

WILL there be another great volcanic explosion from the summit of Lassen Peak this spring? is a burning question among those scientists who are studying the recent performance of that old volcano. A feeble explosion May 30, 1914, opened a new period of volcanic play, and on May 19 and 22, 1915, the greatest and most devastating eruptions occurred. As these dates are about the time of maximum annual snow-melts at Lassen Peak, they suggest a causal relation to the volcanic activity. If so, perhaps another large eruption may be due in May, 1916, and throw more light on the volcanic problem.

Lassen Peak is in northeast California and forms the southern end of the Cascade Range. It stands between the northern end of the Sierra Nevada and the Klamath Mountains, a mighty volcano that rises to an elevation of more than a mile above the early Tertiary and Cretaceous sedimentary rocks on which it rests. It is on the edge of one of the greatest lava fields in the world, extending from northern California, Oregon and Washington eastward across Idaho into the Yellowstone National Park of Wyoming, and covering an area of about 250,000 square miles. Over the eastern portion of this field most of the lava is basalt, which was very liquid at the time of its eruption and, spreading far and wide like water, it formed a flattish country, the great plains of Snake River and the Columbia, but along the western border the lava

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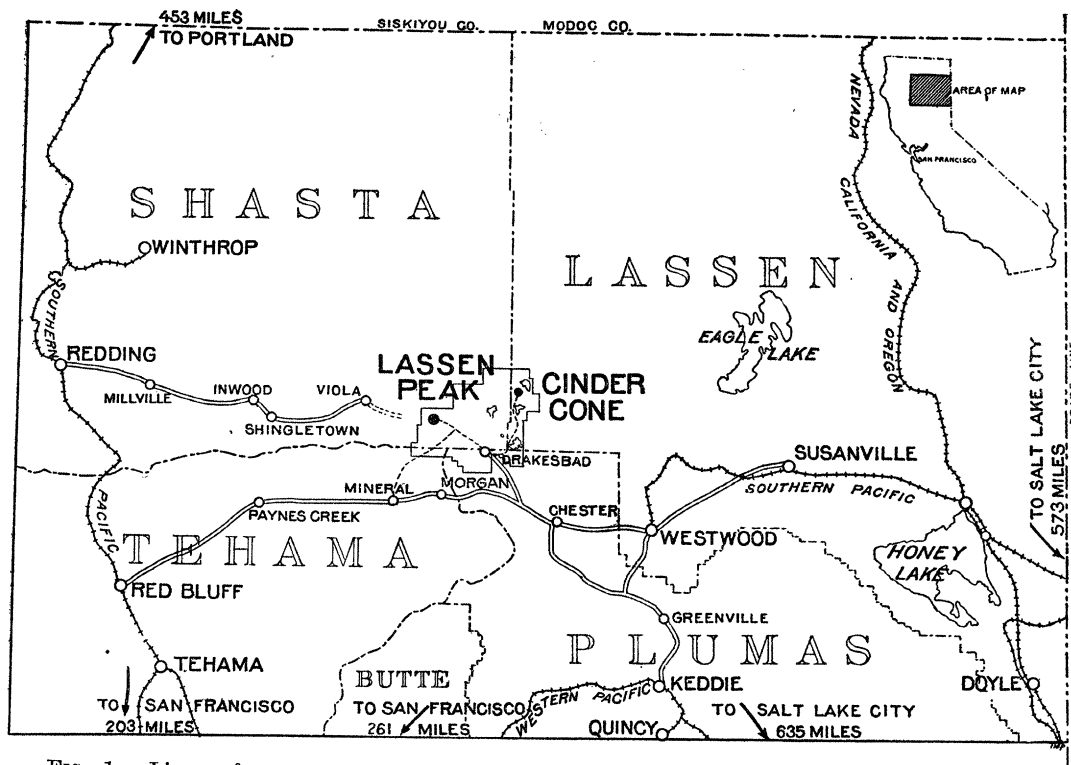


FIG. 1. Lines of approach to the proposed Lassen Volcanic National Park Railroads, wagon roads and trails to Lassen Peak and cinder cone, which are 10 miles apart and within the boundary of the proposed park.

is chiefly andesite, a viscous lava that piled up about the vents from which it issued and built up a range, the Cascade range, surmounted by great peaks, from Lassen Peak, which rises 10,460 feet, to Shasta and Rainier, that attain an elevation of more than 14,000 feet.

In the volcanic belt of the Alaskan Coast there are a number of vigorously active volcanoes. So also in Central America and Mexico, but in the Cascade range the volcanoes appear to be near extinction.

Since the white man settled on our Pacific coast there has been but little volcanic activity. In 1843, about the time Fremont, the pathfinder, made his memorable trip across the continent, Mount Baker and Mount St. Helens in the state of Washington were both in eruption, spreading a blanket of volcanic

dust over the country as far south as the Columbia, where at the Dallas a missionary gave a sample to Fremont.

Professor Davidson, of the United States Coast Survey, in 1854 saw an eruption of Mount Baker. The summit was obscured by vast rolling masses of dense smoke, which in a few moments reached an estimated height of two thousand feet above the summit and soon enveloped it entirely. In 1858 Mr. J. S. Hittell saw the clouds over Mount Baker brilliantly illuminated by an eruption then taking place.²

Mount Rainier and Mount Shasta emit heated vapors from the fumaroles on their summits, giving evidence that their interiors are still hot.

² "The United States," J. D. Whitney, p. 115.

The present activity of Lassen Peak, though feeble as compared with its earlier eruptions, is proof that it must still be classed as an active volcano.

The volcanic activity which resulted in the upbuilding of Lassen Peak began near the close of the Eocene. The lava flows appear to have been largest and most numerous in the Miocene and Pliocene, successive flows decreasing in size during the Quaternary to near extinction in recent times.

There were long periods of interrupted activity separated by long intervals of quiescence. During the active periods both explosive and effusive eruptions were common; the one forming cinder cones and sheets of volcanic agglomerate and tuff; the other forming lava fields whose ruggedness was proportional to the viscosity of the erupting lava.

Lassen Peak is a volcano of large type surrounded by many smaller ones of later date, the whole being built up of a notable variety of lavas. The oldest lavas of the Lassen Peak region are of intermediate chemical composition belonging to andesites. The early magma yielding the erupting andesitic lavas in the course of time differentiated into two portions. On the one hand it became more siliceous (salic), erupting as dacite and rhyolite, and on the other hand it became less siliceous (mafic), yielding basalt and quartz basalt. All varieties are well represented in the Lassen Peak region and are derived apparently from the same magma.

As the volcanic center developed the most active crater migrated. The first crater was in the head of Mill Creek. It was not only the oldest, but also the largest crater, more than a mile in diameter. Composed of andesitic lavas, it rose to a height of 9,400 feet. The peak named "Brokeoff Mountain" on the Forest Service maps is the most prominent remnant of this great crater in the head of Mill Creek.

The second great crater opened on the northern edge of the first and erupted dacite, building up Lassen Peak to its present height with a summit crater about a quarter of a mile in diameter.

The third crater, about four miles a little west of north from the first, opened only a few centuries ago at the northwest base of Lassen Peak, and the rugged lava flows from it formed Chaos Crags.

The products of this eruption in Chaos Crags are well preserved and their relations clearly visible. The eruption began by a succession of explosions that spread a thin layer of volcanic sand and dust over the surrounding country and ended in the extravasation of a most rugged mass of dacite which, though at first glance having the aspect of granite, is rich in volcanic glass, generally of dark color, somewhat pumiceous and full of inclusions like the dacites of Lassen Peak.

The fourth crater of Lassen Peak is the new crater, active at the present time. It began by a slight explosion within the old crater, second of those enumerated, on the summit of Lassen Peak, and is remarkable for its place of outbreak, as well as its low energy, the small mass of material erupted and the continuity of the activity. Like the eruption of a few centuries ago at Chaos Crags, it had two phases, one explosive, the other effusive.

During the first phase the explosive eruptions were of gas carrying out with it rock fragments and dust only. The size of the crater increased with each eruption, as shown in Fig. 2 by the outlines of the new crater June 14, 1914, and March 23, 1915. The second phase, which is effusive, includes also an eruption of lava, which formed a lid on the volcano and overflowed to the west, as represented in Fig. 2.

In the beginning the new crater was confined to the loose material filling the old crater, but later it reached the solid rock

of the old crater rim and finally after more than 150 eruptions it attained near the end of March, 1915, a size of about 700 to 1,000 feet.

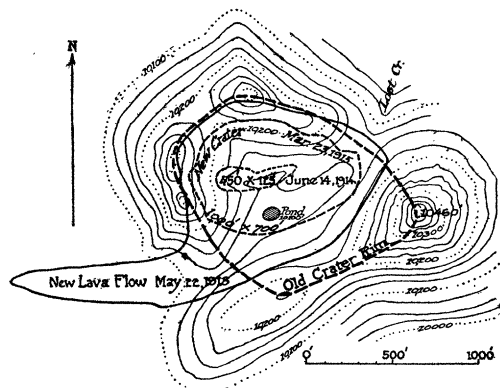


FIG. 2. Sketch contour map of the summit of Lassen Peak by J. M. Howells, June 16, 1914, upon which has been drawn the outline of the old crater rim as well as the outline within it of the enlarging new crater June 14, 1914, and March 23, 1915. The new crater at first lengthened east and west and later widened north and south, in both cases along joint planes, until its dimensions were $1,000' \times 700'$. Then the explosive eruptions gradually became effusive. The lava in the throat of the volcano gradually upheaved during April and May until it filled the old crater and overflowed through the lowest notch and down the west slope about 1,000 feet. The hot blast that devastated Hat Creek escaped from beneath the lava lid at the head of Lost Creek.

Ejecta accumulated on the rim of the new crater to a depth of thirty to forty feet. The largest stone ejected was fifteen feet in diameter and weighed about sixty-three tons. Small stones were thrown as much as a mile from the crater, but beyond two miles from the crater scarcely more than a trace of dust could be noticed except to the northeast, the direction of the strongest winds and that taken by the great blast of the eruption May 22, 1915.

By far the greatest eruptions that have occurred at Lassen Peak since its present activity began are those of the night of May 19 and the afternoon of May 22, 1915.

The first great result was the extrusion of new lava and the formation of a lava lid which culminated in the second great feature, the devastation of the Lost Creek and Hat Creek country by a horizontal blast of hot gas.

About the end of March, 1915, the old crater having been thoroughly cleaned out by explosive eruptions and the superincumbent load largely removed from the magma, it began to rise in the volcanic conduit and initiated the second stage, the effusive stage, of the volcanic activity. The hot magma apparently more or less viscous in the volcanic conduit, was forced upward by pressure of magma or gas from beneath and was gradually upheaved, with great escape of steam, until it reached the surface as new lava, and as a lava table filled not only the new, but also the old crater so as to form a lid on the volcano. The lava overflowing from the edge of the lid through a notch in the old rim, as shown in Fig. 2, passed down the west slope of Lassen Peak about a thousand feet.

On the night of May 19 and especially also on the afternoon of May 22, 1915, the eruptions were violent. A mushroom-shaped cloud was hurled to the height of about four miles above the summit of the mountain and afforded a magnificent spectacle as seen from the Sacramento Valley. At night³ flashes of light from the mountain summit, flying rocket-like bodies and cloud glows over the crater reflecting the light from incandescent lavas below were seen by many observers from various points of view and appear to indicate that much of the material erupted was sufficiently hot to be luminous.

³ Luminous phenomena were reported on the nights of September 29, 1914, May 14, 15, 17 and 19, 1915, as well as June 20 and October 20 of the same year. Some of the phenomena reported may be explained as due to the reflected rays of the setting sun, but this can not be true of all.

Professor R. S. Holway, who was one of the first observers to ascend the mountain after the eruption, saw it on May 27, five days after the eruption, and states that "hissing steam was escaping from many cracks and crevices and the shimmering air above all telling of the hot rocks below."

J. M. Howell's party visited the summit May 30, eight days after the eruption, and Mr. Spaulding reports that

the heat from the upheaved mass was intense. The air above it shimmered with heat waves like the desert on a boiling summer day.

That the new lava in the lid at the time of its eruption was so hot at least in spots as to be luminous appears evident and it is probable that the temperature to produce luminosity, say 600° to $1,000^{\circ}$ C. would at the same time give to the slowly rising lava such a degree of viscosity as to enable it to adjust itself to its surroundings and overflow the crater rim.

Although the lava lid in places appears to be a mass of tumbled rock fragments yet there are large portions of it essentially continuous, as if forced up in viscous condition and broken later as a result of the cooling, flowing and subsidence of the mass within the crater. The postmaster at Manton reports that a change was noticed on the summit of the mountain for a few days previous to May 19. A black wedge-shaped mass of lava appeared in the middle of the new crater, getting higher every day, and finally in plain view spilling over through the notch on the west slope.

Many volcanic bombs were ejected by explosive eruptions during the effusion of the new lava. They range up to five feet or more in diameter and are most abundant at the foot of the steeper portion of the northwest slope. Many of them have a peculiar compact crust with a cracked surface like bread crust, suggesting the name "bread crust bombs," and they are regarded as the

luminous ejecta seen in connection with several eruptions by observers from different points of view. No other portion of the erupted magma afforded such impressive evidence of fusion as the bread-crust bombs.

Although the extrusion of the new lava and the formation of the lava lid was the main feature of the great eruptions in May, it was far surpassed in interest and wonder by the remarkable horizontal eruption of the hot blast that devastated Lost and Hat Creeks.

On the night of May 19, it appears that the body of superheated gases which accumulated beneath the lid, forcing it up, escaped from under the edge with terrific force down the deep snow-covered northeast slope of Lassen Peak toward Lost Creek and Hat Creek. The snow was instantly converted into water, and the mighty onrush of water and blast of hot gases swept everything before it for more than ten miles along Lost Creek, forming a devastated belt from a few hundred yards to a mile in width. Meadows were buried beneath finer débris and occasional large boulders broken off from the edge of the lava lid far above. Trees three feet in diameter were broken off or uprooted and the country scoured as by a mighty sand blast. The fine green leaves of the pine trees left standing along the borders of the blast were killed by the heat and turned brown. Locally, on favorable slopes, the heat was so great that the green leaves were charred. Not only those of the pine, but also those of the Manzanita, several acres of which, at a distance, had the general appearance of an area swept by a forest fire. In fact it is stated by Mr. Fred Seaborn, of the Forest Service, who was in that region a few days later, that two fires were actually kindled by the eruption.

This reminds one of the hot blast from

Mount Pelée that destroyed St. Pierre. Luckily in the Hat Creek region there were only a few summer residents. Warned by the noise of the approaching torrent, they escaped to the hills.

That no one was killed was simply a matter of good fortune on the part of the eleven enthusiasts who early visited the region to make a photographic record. Mr. B. F. Loomis, the veteran photographer of Viola, was among them.

There were two hot blast eruptions into the Hat Creek country; one on the night of May 19 and the other on the afternoon of May 22.

The Loomis party arrived on the scene about noon, May 22, and spent several hours photographing up to the head of Lost Creek, making a record of what was accomplished by the first blast. They left soon after 3 o'clock and had scarcely reached the west side of Chaos Crags when the most violent eruption occurred, sending its column of smoke to a height of more than 20,000 feet, as seen from the Sacramento Valley, and a hot blast down the slope into the Hat Creek country that would probably have killed the whole party had the eruption occurred a few hours earlier.

At the time of the great outbreak a fissure was opened running from the summit northwest about 1,000 feet down the slope toward Chaos Crags. Three vents were opened on this fissure, and the greater portion of the volcanic activity during the summer of 1915 was confined to this fissure. G. W. Olsen, who ascended Lassen Peak October 19, 1915, reported the northwest fissure quiet, but another one active a few hundred feet east of it on the northern rim of the lid.

Fumaroles have developed at a number of points on the north and west slopes of Lassen Peak within 800 feet of the summit, but all the violent eruptions have occurred at or

very near the summit. No fumaroles have appeared on the south and east slopes, the direction of easiest approach, where at lower levels, 5,800 to 7,400 feet, fumaroles and solfataras are such active features at Bumpass' Hell, the Devil's Kitchen, and Tartarus or Boiling Lake. These solfataras within three miles of Lassen Peak have been active with but little change during the last fifty years. They are on the strongest side of Lassen Peak and have not been affected by the eruptions at its summit, 4,000 feet above them.

The total mass of material transferred from within the mountain to the surface by the explosive and effusive eruptions during the twenty-two months since the beginning of volcanic activity at the summit of Lassen Peak is very small as compared with the results of volcanic eruptions generally, and yet its small size and high point of activity may be important factors in discovering its cause.

In any discussion as to the cause of the recent eruptions a record of the facts as to time and energy is fundamental.

The Forest Service at Red Bluff, W. J. Rushing in charge, furnished most of the important data during the summer when the rangers were in the field, but at other times Miss Alice Dines, postmaster at Manton, and G. W. Olsen at Chester, both living in sight of the mountain, supplemented the record. The eruptions have been tabulated as to time, intensity and duration, and the tabulation has a more or less evident bearing as to the efficiency of certain causes that may affect the eruptions.

The variation as to time of day at which eruptions occur is very irregular and one time of day appears about as favorable as another for eruption. Of the 220 eruptions up to the end of January, 1916, 143 occurred in the day time, while 77 occurred at night, that is between 7 P.M. and 7 A.M.

In the day time 57 eruptions occurred between 7 and 11 A.M., 40 occurred about noon, between 11 A.M. and 3 P.M., while between 3 and 7 P.M. 46 occurred. It has been supposed that a greater supply of surface water might favor eruption. If that is true, we should expect more frequent eruptions in the late afternoon or early evening when the day's supply of water from melting snow is at its maximum. On the contrary, the mornings have most eruptions, at a time when the daily heat and water supply are near their minimum.

That the volcanic energy is not dependent upon the supply of surface water to form steam is suggested by the fact that summer and autumn, the dry season, with least water, have a greater number (94) of eruptions than (84) the wet season of winter and spring.

In order to determine whether the volcano responds to the tidal wave produced in the crust of the earth by the moon, Mr. Van Orstrand has carefully considered 190 of the best recorded eruptions and concludes that as yet the results are merely suggestive.

If we compare the number of corresponding seasonal eruptions in 1914 and 1915 the result appears significant. In the summer of 1914 there were 38 eruptions, but in 1915 only 17. In the autumn of 1914 there were 56 eruptions, while in 1915 there were only 22. Since the great eruption of May 22, 1915, when the new lava was extruded and the Hat Creek country devastated, the number of eruptions has decreased and the decadence continues, but whether or not the active period of Lassen Peak is approaching its close, although probable, may be more certainly told next summer.

With its comfortably active volcano, inviting cinder cones and lava fields, vigorously boiling hot springs, mud lakes and "mush pots" for the vulcanologist to study, and the glaciated divides and canyons for

the physiographer, in a setting of lovely scenery and attractive camps, for the tourists all easily accessible, the Lassen Peak region affords one of the most alluring and instructive spots for a national park.

J. S. DILLER

U. S. GEOLOGICAL SURVEY,
WASHINGTON, D. C.,
April 18, 1916

THE NEED FOR MORE HORTICULTURAL RESEARCH¹

IN order to introduce my subject I hope I may be pardoned for digressing a moment. A few years ago while spending a part of a vacation in the Sierras, I climbed from the floor of Yosemite valley to the top of Glacier Point. To those of you who have been there I need not say that this climb required several hours of very severe physical effort. In traveling a mile and a half or less, the vertical ascent amounted to three thousand feet. I was accompanied by my wife, and being mindful of her safety as well as my own, I very naturally chose each step of the climb with great care. Often a contemplated step might look safe enough but, on glancing into the depths below, I would feel the necessity for making a more careful examination of the footing before risking my weight upon it. There were numerous instances when a false step might have sent us both hurtling downward, and it really is not pleasant to contemplate a half-mile drop into space even when accompanied by good company. Sometimes what appeared to be firm soil on a ledge turned out to be sand, or what looked like solid rock proved to be loose stones concealed by moss and lichens. Thus the journey was made without mishap, but slowly, tediously, because

¹ President's address delivered before the twelfth annual meeting of the Society for Horticultural Science, Columbus, Ohio, December 28, 1915.